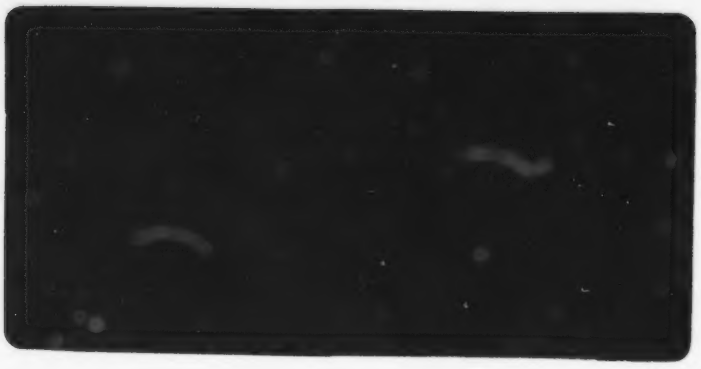

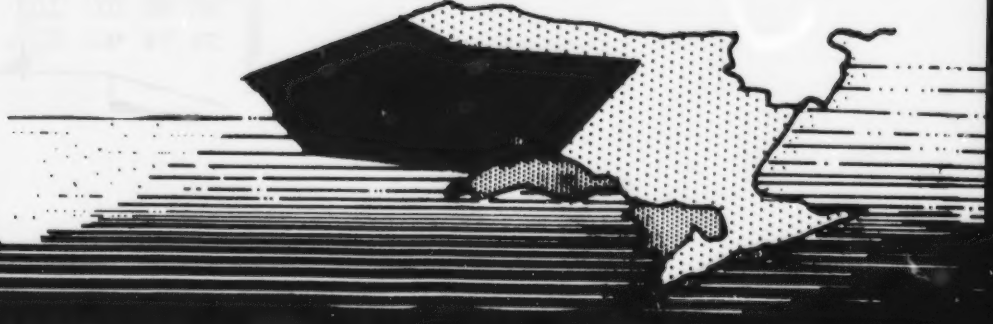

Ontario Ministry of Natural Resources

NORTHWESTERN ONTARIO FOREST TECHNOLOGY DEVELOPMENT UNIT

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CAN JACK PINE SITE PRODUCTIVITY IN NORTH CENTRAL ONTARIO BE PREDICTED USING MULTIPLE REGRESSION SOIL-SITE EQUATIONS?

by

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ABSTRACT

Recent studies of jack pine (Pinus Banksiana Lamb.) soil-site relationships for the B.9 Superior and the B.10 Lake Nipigon forest sections (Rowe 1972) in north central Ontario provide an excellent insight into the relationships between jack pine site productivity and the features of soil and topography. Site productivity is most commonly described using the measure of site index. Site index is the average height of dominant trees on a site at a standard reference age (usually 50 years breast height age). It is therefore similar to the concept of site class presently used in Ontario.

Soil-site relationships, if properly constructed and verified for a unit, district or region, will permit a technician or forester to rate the relative productivity of a given site using site index values. Knowing the site index value for a species will also allow the manager to access the provisional managed stand yield tables for Northwestern Ontario. From these we can estimate future crop volumes, rotation ages and spacing-volumes relationships. Because this site productivity information is useful to crop planning, the soil-site relationships must be accurate.

The objective of this study was to independently examine the application of Schmidt and Carmean's (1988) multiple regression equations describing jack pine soil-site relationships for the Thunder Bay District and the B.8 Central Plateau and B.11 English River forest sections. Soils and jack pine site index data from 84 Forest Ecosystem Classification (FEC) plots located on various site conditions across the B.8 and B.11 forest sections were used to test the hypothesis that these soil-site relationships could be applied across north central Ontario.

Schmidt and Carmean's (1988) equations for predicting site index on outwash glacial sands accurately estimated jack pine site productivity irrespective of location. However, the multiple regression equations available for shallow to bedrock morainal soils and deep morainal soils did not accurately estimate jack pine site productivity. The accuracy and reliability of an equation for the glacio-lacustrine landform could not be independently tested, due to a lack of independent verification plots.

Schmidt and Carmean's (1988) multiple regression equations and site index prediction tables should only be used to predict jack pine site productivity (site index) in the Thunder Bay - Nipigon area of the B.9 and B.10 sections. A more encompassing soil-site study is required in north central Ontario in order to produce equations and tables capable of predicting jack pine site productivity on the other major landform conditions.

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Final responsibility for the content and views are those of the authors.

INTRODUCTION

Forest managers require site productivity and stand yield information organized within a land classification framework to assist them in making objective decisions about timber management practices (Figure 1) (Carmean 1977).

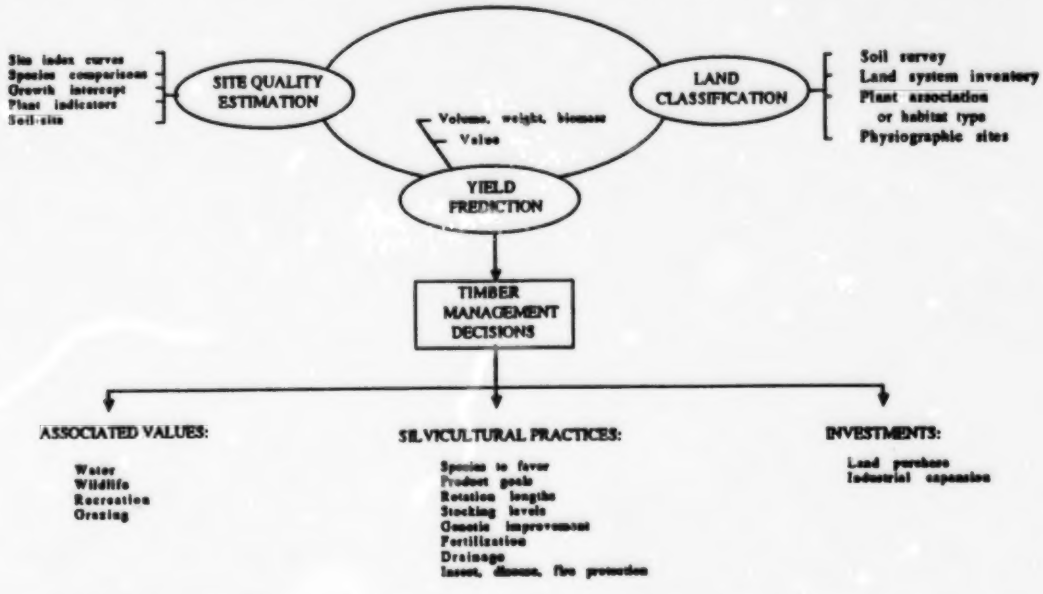

Figure 1. Decisions concerning intensive forest management depend upon a complementary framework of site quality estimation, yield prediction, and forest land classification (Carmean 1977).

Schmidt and Carmean's (1988) soil-site study is currently the most reliable and accurate information source describing the relationship between jack pine site productivity and features of soil and topography in north central Ontario. Site productivity is most commonly described using a measure of site index which is the average height of dominant trees at a standard reference age (usually 50 years breast height age), and is similar to the concept of site class presently used in Ontario.

It would seem logical to utilize Schmidt and Carmean's (1988) soil-site relationships for identifying jack pine productivity. However, since this work has been derived from data collected in the Thunder Bay - Nipigon districts

(i.e. B.9 Superior and B.10 Nipigon Forest Sections), its application to other districts in north central Ontario (i.e. B.8 Central Plateau and B.11 English River) must first be tested.

The objective of this study is to independently examine the application of Schmidt and Carmean's (1988) jack pine soil-site relationships to the Atikokan, Geraldton and Terrace Bay administrative districts, Ontario Ministry of Natural Resources.

LITERATURE REVIEW

Schmidt and Carmean's (1988) Soil-Site Study

Schmidt (1988) made a soil-site study for jack pine in north central Ontario (Figure 2). The study area covering less than 50 percent of the total production forest, is completely within the North Central Region of the Ministry of Natural Resources.

Schmidt established plots in stands which had previously been sampled, to formulate new regional jack pine site index curves (Lenthall 1986). The stands were mature (older than 50 years), well-stocked, even-aged, and undisturbed. An average site index value for the jack pine at each site was determined from the stem analysis of three to five well-formed, uninjured, dominant and codominant jack pine trees growing on each plot.

This study successfully identified some relationships that existed between jack pine site productivity (site index) and features of soil and topography; site index prediction equations based on multiple regression analysis were developed (Table 1). The multiple regression equations were then used to create site index prediction tables (Table 2).

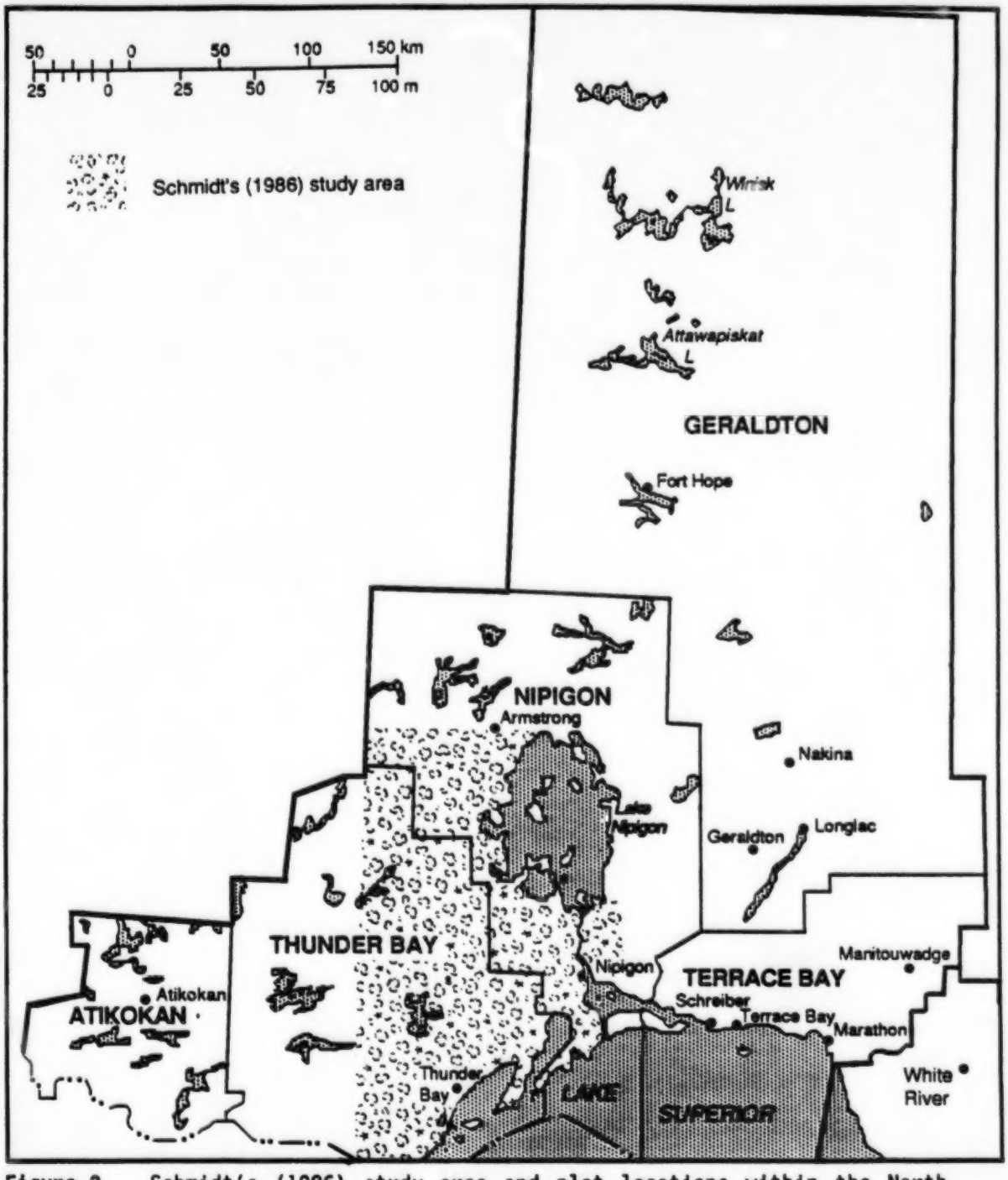

Figure 2. Schmidt's (1986) study area and plot locations within the North Central Region, OMNR.

Table 1. Multiple regression equations expressing the relation between site index of jack pine and features of soil and topography for four general soil groups in north central Ontario (Schmidt and Carmean 1988).

Soil group	No. of plots	Equation	R2	SEE
Shallow morainal soils	20	SI= 9.42 + 0.11DBR - 0.0006(DRBxCoFrag A)	0.83	1.28
Deep morainal soils	30	SI= 18.54 + 0.00051[DRL(10-CoFrag C0] - 0.38 CIA	0.65	1.26
Outwash glacial soils	31	SI= 17.56 + 0.10DRL - 0.73 Slope - 0.0044[DRL(20-Slope9]	0.65	1.26
Glacial lacustrine soils	18	SI= 25.38 + 0.018(ThA)2 - 0.24 (Ph BC)2	0.75	1.07

The multiple regression equations were then used to create site index prediction tables (Table 2).

The site index prediction equations and tables produced from this soil-site study can be used to estimate the quality of any site within Thunder Bay and Nipigon District's where these landforms occur. To directly determine the site productivity for jack pine on a given site, one can directly measure the height and age of jack pine and determine a site index value from site index curves (i.e. Plonski 1981; Lenthall 1986). However, there must be an ample number of jack pine trees growing, in well-stocked and undisturbed stands for measurement.

If the site currently supports: 1) stands that are composed of species other than jack pine; or 2) stands that have only scattered jack pine; or 3) stands which are very young (<25 years old); or 4) stands which are partially or completely cut; or 5) stands that are poorly stocked, then the site productivity for jack pine must be determined indirectly using soil-site relationships, or soil-site information. One can assess the site productivity for jack pine on any site that has known soil features. This ultimately allows site quality comparisons to be made between areas that currently do not support jack pine as a crop species.

Table 2. Site index prediction tables for jack pine on four general glacial soil groups in north central Ontario (Schmidt and Carmean 1988).

A) Shallow to bedrock morainal soils

Depth to Bedrock (cm)	Coarse Fragments in A Horizon (%)			
	0-15	15-30	30-50	50-70
0-15	10.2	10.2	10.1	10.0
15-30	11.8	11.6	11.4	11.1
30-50	13.7	13.4	12.9	12.5
50-70	15.9	15.3	14.7	14.0
70-100	18.6	17.8	16.9	15.9

B) Deep morainal soils

	Depth to root restricting layer (cm)**								
	0 - 30			30 - 70			70 - 100		
% clay in A Horizon	CoFragC (%)***			CoFragC (%)***			CoFragC (%)***		
	10-40	40-70	70-100	10-40	40-70	70-100	10-40	40-70	70-100
	-------SI-------			-------SI-------			-------SI-------		
2 - 4	18.0	17.7	17.5	19.3	18.6	17.8	20.7	19.4	18.1
5 - 7	16.8	16.6	16.4	18.2	17.4	16.6	19.5	18.2	16.9
8 - 10	15.7	15.5	15.2	17.0	16.3	15.5	18.4	17.1	15.8

C) Outwashed glacial sands

Depth to root-restricting layer**** (cm)	Percent Slope			
	0-3%	3-6%	6-9%	9-12%
	-------Site Index (m)-------			
0 - 30	16.7	14.8	12.8	10.8
30 - 60	17.3	15.7	14.1	12.5
60 - 90	17.9	16.7	15.5	14.3
90 - 120	18.4	17.6	16.8	16.0

D) Glacial lacustrine soils

Thickness of A horizon (cm)	pH of BC Horizon			
	4.8 - 5.3	5.3 - 5.9	5.9 - 6.5	6.5 - 7.0
	-------Site Index (m)-------			
0 - 4	19.2	17.8	16.1	14.4
4 - 8	19.9	18.5	16.8	15.0
8 -12	21.1	19.7	18.00	16.3
12 -14	22.2	20.8	19.1	17.3

*Site index is the total height (m) of dominant and codominant trees at 50 years breast height age.
**Depth to root restricting layer (basal till, bedrock, mottles, gley, water table, till, or carbonates).
***Percent coarse fragments in C horizon.
****Coarse sand, mottles, gley, and (or) water table

Height Growth as a Standard for Estimating Site Productivity

Of the many different methods available for describing site productivity, the use of tree height at a standard reference age is widely accepted in North America and Europe (Carmean 1975, Hagglund 1981). The use of height growth is logical as it is closely related to volume growth which, the ultimate measure of site productivity (Carmean 1975). Spurr and Barnes (1980) emphasize this, stating that "...the height of free-grown trees of a given species are more closely related to the capacity of a given site to produce wood than any other single measure." Height growth of dominant and codominant trees is also relatively unaffected by stand density or stocking (Rudolph 1951; Ralston 1953, Ware and Stahelin 1948).

Use of Breast-Height Age with Height Growth

Initial height growth of most tree species is slow and erratic, is not closely related to site index, and has little relation to height growth above breast-height (Ferree et al. 1958; Day et al. 1960; Richards et al. 1962; Lenthall 1986; Thrower 1986). However, after researching breast-height (i.e. 1.3m) height growth is more rapid and consistent, and becomes closely related to site productivity. Early height growth below breast-height varies up to 10 years for many species (Carmean 1975), and greatly reduces the accuracy of site index curves based on total age. More accurate site index curves can be developed using breast-height age (Husch 1956), thus eliminating the variability of erratic early growth below breast-height.

Early erratic height growth is caused by many non-site factors including weed and brush competition, frost damage, animal and insect injury, differences in stock quality, and planting techniques (Carmean 1975). Spurr and Barnes

(1980) state that early erratic growth is caused by climate, topography, soil, moisture, and biological factors. Eliminating this slow and erratic early height growth results in site index curves expressing more accurate relationships between height growth and site productivity.

METHODS

Study Area

The study area is the Ontario Ministry of Natural Resources North Central Region. This area is immediately northwest of Lake Superior, extends from west of Atikokan to east of Manitouwadge and Marathon and to 125 km north of Lake Nipigon (Figure 2).

The North Central Region is characterized by a wide diversity in geology, soils, climate, and vegetation. The region encompasses Rowe's (1972) B.8, B.9, B.10, B.11, and L.11 Forest Sections. The landforms of this glaciated area are mainly ground moraines, followed by lacustrine deposits and bare bedrock (Day et al. 1986). Outwash and aeolian deposits are also common, with minor areas of eskers and end moraines.

Forest cover is extremely variable, ranging from mixed types with luxuriant shrub under-growth to floristically poor, dominant conifer overstory (Rowe 1972). Jack pine is commonly found on dry sand and rocky sites, and black spruce is common on peat-filled depressions and moist uplands. Cedar and tamarack are also found in conjunction with black spruce on wet sites. A mixed forest of white spruce, balsam fir, white birch, and trembling aspen is characteristic on lacustrine deposits. Red and white pine are found as scattered individuals or small clumps. White birch is prominent on till slopes and the tops of low hills.

The Data

Jack pine height-age and soil-site data was obtained for 84 plots that contained dominant or codominant jack pine trees and which were part of the North Central Ontario Forest Ecosystem Classification (FEC) data base (Sims et al 1989). Fifty-eight plots were located in pure, even-aged jack pine stands, while the remainder were located in jack pine dominated mixedwood stands. Total height and breast-height age data were available for three or more dominant and codominant trees on each plot. Landform information and complete soil profile descriptions were also available.

Height and breast-height age values for the three individual jack pine on each plot were then used in conjunction with recently developed ploymorphic height age curves for jack pine in north central Ontario (Carmean and Lenthall 1988) to determine a site index value.

Testing the Accuracy of Schmidt and Carmean's (1988) Site Index Prediction Equations

The difference between the predicted and observed site index versus actual site index, stratified by landform, was tested; Chi-square analysis at a 95 percent confidence level was utilized for a shallow to bedrock morainal soils, deep morainal soils, and outwash glacial sands. Plot data from glacio-fluvial sites whose slopes were greater than 12 percent were omitted, since Schmidt's glacio-fluvial equation only applies for sites with a maximum slope of 12 percent.

RESULTS

Predicted versus Actual Site Index by Landform

Schmidt and Carmean's (1988) soil-site equations and associated significant variables successfully predicted jack pine site index values for stands growing on glacio-fluvial deposits across north central Ontario. However, the equations were not accurate in predicting jack pine site index values for trees growing on shallow to bedrock, and deep morainal sites across the region (Table 3).

DISCUSSION

The predicted site index of jack pine on the outwash glacial sands landform conformed to the observed site index well, and was accepted by the Chi-square test at a 95 percent confidence level. However, the shallow to bedrock morainal and deep morainal landforms did not predict the observed jack pine site index values on these land forms accurately or consistently. Shallow to bedrock predicted jack pine site indices on the shallow to bedrock moraines were consistently lower by two to three metres, while predicted site index values on the deep morainal were consistently higher by one to nine metres. As a result, the soil site predictive models for these two landforms were rejected.

Schmidt and Carmean's (1988) site index prediction equations and tables appear to be only applicable to the outwash glacial landform deposits of the B.8 Central Plateau and B.11 English River Forest Sections, in addition to the full range of land forms in the original B.9 Superior and B.10 Lake Nipigon Forest Sections. This test using independent data also demonstrated that site indices of jack pine growing on the shallow to bedrock morainal and deep morainal landforms could not be accurately predicted with the equations.

Table 3. Predicted versus actual site index stratified by landform for: a) outwash glacial sands; b) shallow morainal sites; and c) deep morainal sites.

A) OUTWASH GLACIAL SANDS

Predicted Site Index	Actual Site Index	Predicted minus actual	Chi-Square
18.76	18.50	+0.26	0.00
18.76	18.38	+0.38	0.01
17.60	14.16	+3.44	0.67
18.76	20.90	-2.14	0.24
16.44	19.84	-3.40	0.70
18.34	16.18	+2.16	0.25
18.45	15.34	+3.11	0.52
17.31	17.99	-0.68	0.03
16.95	16.32	+0.63	0.02
15.86	18.88	-3.02	0.58
17.02	16.40	+0.62	0.02
18.47	16.00	+2.47	0.33
16.44	17.18	-0.74	0.03
18.18	16.56	+1.62	0.14
18.18	17.81	+0.37	0.01
18.76	18.55	+0.21	0.00
16.60	15.97	+0.63	0.02
17.97	15.85	+2.12	0.25
17.81	16.06	+1.75	0.17
17.96	16.61	+1.35	0.10
17.89	17.58	+0.31	0.01
18.76	15.14	+3.62	0.70
18.76	17.46	+1.30	0.09
17.89	18.30	-0.41	0.01
18.76	15.78	+2.98	0.47
18.76	16.01	+2.75	0.40
13.73	20.38	-6.65	3.22
17.35	13.14	+4.21	1.02
13.56	15.45	-1.89	0.26
17.02	17.90	-0.88	0.05
18.76	16.71	+2.05	0.22
14.99	17.30	-2.31	0.36
17.02	18.33	-1.31	0.10
18.76	17.79	+0.97	0.05
18.18	18.03	+0.15	0.00
14.99	17.73	-2.74	0.50
17.74	16.74	+1.00	0.06
16.75	19.39	-2.64	0.42
16.44	19.10	-2.70	0.44
18.76	16.77	+1.99	0.21

X2(35) = 12.69
F(x) = 25.70
ACCEPT

B) SHALLOW TO BEDROCK MORAINAL

Predicted Site Index	Actual Site Index	Predicted minus actual	Chi-Square
17.54	16.47	+1.07	0.07
12.09	16.93	-4.84	1.94
10.61	17.10	-6.49	3.96
15.53	15.73	-0.20	0.00
14.30	17.26	-2.96	0.61
13.53	13.25	+0.28	0.01
9.84	15.07	-5.23	2.77
11.70	15.51	-3.81	1.24
10.01	15.74	-5.73	3.29
13.63	17.66	-4.03	1.19
11.27	16.44	-5.17	2.37
14.56	17.17	-2.61	0.47
12.30	16.11	-3.81	1.18
11.92	16.57	-4.65	1.82
15.71	16.64	-0.93	0.05
9.86	9.51	+0.35	0.01
13.60	16.37	-2.77	0.56
14.92	18.38	-3.46	0.80

X2(18) = 22.34
F(x) = 8.67
REJECT

C) DEEP MORAINAL SOILS

Predicted Site Index	Actual Site Index	Predicted minus actual	Chi-Square
22.75	17.72	+5.03	1.11
17.94	17.21	+0.73	0.03
19.98	17.31	+2.67	0.36
21.51	15.05	+6.46	1.94
23.51	14.26	+9.25	3.64

X2(7) = 7.08
F(x) = 0.71
REJECT

No comment can be made on the accuracy of the site index prediction equation's assessment of jack pine site quality on glacial lacustrine landforms, as this landform was not represented in the independent data.

Although Schmidt and Carmean's (1988) multiple regression soil site productivity relationships were statistically accurate and reliable for describing the variation in jack pine site productivity, soil variables included in the regressions should not necessarily be considered the causal soil features that truly influence or control height growth of jack pine. A valid criticism of stepwise regression analysis is that no qualifiers or non-quantifiable variables (e.g. slope location, understory vegetation, humus form) are included in the regression equations (Monserud 1984). Hence, regression analysis will not include any qualifiers that may have significant effects on the height growth of jack pine, although the analysis will show trends, or combinations of soil features which are associated with tree height growth.

The soil features that multiple regression include as being associated with height growth may, in fact, be influenced by soil features that are not quantifiable, and not described by regression analysis.

CONCLUSIONS

An independent test of the accuracy of Schmidt and Carmean's (1988) site index prediction equations and tables for predicting jack pine site productivity with soil-site variable indicated that the soil-site relationships described for the outwash glacial sands landform were applicable to the B.8 Central Plateau and B.11 English River Forest Sections. However, neither the shallow to bedrock morainal or deep morainal landforms had jack pine soil-site relationships applicable to these Forest Sections.

The glacial lacustrine landform was not tested.

In developing a viable tool to classify site productivity throughout the north central Ontario, it is recommended that an expanded soil-site study for jack pine be undertaken. This new soil-site study should be based on data obtained across the entire geographic area of north central Ontario. Cluster analysis should be used instead of regression analysis, so that all non-quantifiable soil variables (e.g. slope location, understory vegetation), which may be important in relating soil features to the growth of jack pine can also be included in the analysis.

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